Wave-Ice and Air-Ice-Ocean Interaction During the Chukchi Sea Ice Edge Advance

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Award Numbers: N00014-13-1-0435; N00014-13-1-0434; N00014-13-1-0446
http://www.apl.washington.edu/project/project.php?id=arctic_sea_state

LONG-TERM GOALS

Ocean Heat: In the new Arctic summer ice regime, with extended open water periods in areas previously covered with sea ice, ocean heat, received during these summer ice-free periods, may be either confined to the surface mixed layer or enter deeper ocean waters. Our goal is to determine the amount and disposition of ocean heat received and determine whether it is exhausted during fall freeze-up and affects only initial ice growth or, remains in the ocean and has residual effects on ice growth during winter and spring.

Sea State Regime: Large expanses of ice-free water in the Chukchi Sea in the late summer have potentially changed the impact of fall storms by creating wave fields in the vicinity of the advancing ice edge. A goal is to determine if larger amounts of frazil ice and increased turbulence levels in the water column result, leading to significant increases in pancake ice formation and higher incorporation of sediment into pack ice in the continental shelf regions.

OBJECTIVES

- Conduct a complete (the first) wave-ice interaction field experiment that adequately documents the relationship of a growing pancake ice cover with a time and space varying measured wave fields
- Document the state of sea ice advance, i.e., rate of advance, sea ice properties and thickness evolution, and compare rates relative to presence/absence of waves and on changing heat/freshwater content

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2013		**00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Wave-Ice and Air-Ice-Ocean Interaction During the Chukchi Sea Ice Edge Advance	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Texas San Antonio,San Antonio,TX,78249**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

- Document the state of ocean-atmosphere-ice interactions before and during the autumn sea ice advance to assess seasonal changes in ocean heat/freshwater content and effects on ice-ocean interactions post ice formation
- Provide the necessary data to allow ocean-atmosphere-ice interactions and pancake ice growth at the advancing ice edge, including waves, to be correctly parameterized in the next generations of ice-ocean coupled models and wave prediction models
- Provide the necessary data to improve and refine remote sensing algorithms that aspire to describe sea ice morphology (signatures of brash, pancake ice and young congelation ice) during sea ice advance.

APPROACH

The principal field activity of the SeaState DRI will be a 38-day cruise on the R/V Sikuliaq in Sept-Oct 2015. Within the full suite of ice-wave and ocean- ice-atmosphere interaction studies that will be needed in this work, we propose a comprehensive, multiplatform suite of measurements that will characterize the ice cover and upper ocean, and importantly, their co-evolution over spatial scales that can capture their horizontal (i.e., north-south) variability during the ice edge advance. The Table lists the instrumentation and parameters that will be measured using the ship platform and buoys deployed during the cruise to achieve our main objectives.

Instrument	Location	Physical Component	Measurements	Duration	Lead
Ocean gliders	Ahead of ice edge	Upper ocean (0-200m)	T, S, O2, bio-optics, currents	During cruise	CU-B UAF
Autonomous underwater vehicle (AUV)	Under ice, up to 50km transects	Ice thickness, floe-size distribution, waves, upper ocean properties	ADCP, CTD, camera,multibeam sonar	During cruise	WHOI
Acrobat Towed Vehicle; CTD casts; Upper Ocean Buoys	Ahead, at and inside ice edge; Stations and Underway	Upper Layer Properties of Polar Ocean (2-300 m)	Discrete T; S at one level (UpTempo buoys); profiling CTD casts; Acrobat Towed Vehicle	~1 year (buoys) and During cruise	CU-B UAF UW
Airborne expendable Ice Buoy (AXIB)	Ahead, at and inside ice edge	Surface meteorology	T, SLP	~1 year	CU-B UW
Unmanned Airborne Vehicle (UAV)	Ice edge vicinity	Surface characterization, ice concentration, floe size distribution	Airborne digital photography	During Cruise	WHOI
Electromagnetic Induction (EMI)	Underway in sea ice	Snow/sea ice thickness	Conductance estimated thickness	During cruise	UTSA
Marine Lidar	Underway in sea ice	Surface Topography	Range and Elevation	During cruise	UTSA
Stereo digital camera	Underway in sea ice	Sea ice concentration, type and floe distribution	Digital (stereo) photography	During cruise	UTSA
Ice Mass Balance (IMB) buoys	Inside ice edge w/ >50cm thickness	Ice mass balance	T in snow-ice-ocean, T, SLP at surface	~1 year	WHOI CRREL

(SeaState DRI Investigator by Institution Team: Ackley-UTSA; Maksym-WHOI;Stammerjohn CU-B)
(Guest Investigator(s) by Institution Team: Winsor-UAF; Steele&Rigor-UW; Perovich-CRREL)

WORK COMPLETED

(Ackley,Maksym,Stammerjohn) The field program part of the science plan strategy was written including preparation of figures the instrumentation tables and deployment schematic diagram, cruise track map, and summary table of processes to be investigated, including all other DRI investigations as well as the Ocean Heat and Ice-Wave interaction studies under this set of grants. Commitments for deployment of additional buoys were received from U of Washington and CRREL.Mike Steele and Ignatius Rigor (UW) plan to have us deploy UpTempo Buoys (Steele) and AXIB or SVP buoys (Rigor) which will augment the DRI, as well as satisfy their program objectives. Don Perovich (CRREL) has also committed two CRREL Ice Mass Balance Buoys, which together with buoys from WHOI (see below) will increase our probability of monitoring ocean heat flux throughout the winter period from initial ice growth to spring-summer decay.

(Ackley) Preliminary discussions with C. Glennie of NCALM have confirmed the feasibility of using Marine Lidar for ice surface roughness and subcontracting NCALM to provide the equipment and operator for the 2015 cruise. Initial discussions were held as to the possibility of using the same lidar on different mounts at different times to also operate from the surface and, possibly, nadir looking to monitor waves for the atmospheric boundary layer investigations (Guest/Fairall/Persson). We completed cataloguing and started orthorectification processing of ship-based camera imagery obtained during a recent cruise through the Antarctic ice edge. These images will provide a test bed for determination of floe size distributions and ice concentration parameters that are planned to be obtained from the similar cameras we will deploy during the DRI cruise for investigations of ice-wave interaction.

(Maksym) Planning options for the IMBS/GPS/AWS array were initiated, primarily looking at available technologies at WHOI to improve on some aspects of the SAMS IMBs - notably, improve GPS accuracy and add sensors, such as acoustic pingers to improve accuracy. Deployment planning for AUVs was initiated. A separate project to deploy an AUV under sea ice in the Beaufort/Chuckchi Seas aboard the USCGC Healy was leveraged(Sept 2013) to test the mapping of ice floe size distribution and thickness in the marginal ice zone using the WHOI Jaguar AUV. This data will be analyzed to refine strategies for the Sikuliaq 2015 cruise.

(Stammerjohn) Discussion with Peter Winsor, U of Alaska, resulted in plans for his contributions of instrumentation, two gliders and the Acrobat towed vehicle, to be used in the Sikuliaq 2015 cruise, significant additions (at minimal cost) to the regional study of ocean heat and sea state during the cruise. Work was initiated on creating and refining analytical tools for processing/analyzing hydrographic data from the multiple platforms that will be deployed during the 2015 cruise.

RESULTS

All activities were focussed on planning and, with the experimental/field nature of this investigation, no results are expected until after the field data is obtained in 2015.

IMPACT/APPLICATIONS

No significant applications as yet.

RELATED PROJECTS

Within the Sea State DRI(list below), the most closely related project is the theory/modeling studies of Hayley Shen at Clarkson University (hhshen@clarkson.edu). Photographs from a ship-based camera were reviewed and discussed related to the parameters derivable from these field investigations on floe size distributions, ice concentration and ice thickness, parameters needed in her analytical modeling simulations of ice-wave interaction.

An Arctic Ice/Ocean Coupled Model with Wave Interactions

Squire, Williams, and Holt

Wave–Ice Interaction in the Marginal Ice Zone: Toward a Wave–Ocean–Ice Coupled Modeling System

Rogers

An Integrative Wave Model in the Marginal Ice Zone Based on a Rheological Parameterization

Shen

Proving and Improving Wave Models in the Arctic Ocean and its MIZ

Wadhams and Doble

Wave Climate and Wave Mixing in the Marginal Ice Zones of Arctic Seas: Observations and Modeling

Babanin

Storm Flux: Heat and Momentum Transfer in the Arctic Air–Sea–Ice System

Thomson

Quantifying the Role of Atmospheric Forcing in Ice Edge Retreat and Advance Including Wind–Wave Coupling

Fairall, Persson, and Guest

Wave–Ice and Air–Ice–Ocean Interaction During the Chukchi Sea Ice Edge Advance

Ackley, Maksym, and Stammerjohn

Radar Remote Sensing of Ice and Sea State and Boundary Layer Physics in the Marginal Ice Zone

Graber

Wave Processes in Arctic Seas Observed from TerraSAR-X

Gemmrich and Lehner

PUBLICATIONS

Thomson, J. et al, Sept 2013, Sea State and Boundary Layer Physics of the Emerging Arctic Ocean: Science Plan, Tech Report, APL-UW-TR1306, Applied Physics Lab, UW, Seattle, 59pp [published] Available at:
http://www.apl.washington.edu/project/project.php?id=arctic_sea_state